NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE ARTHUR

(AL012014)

1 – 5 July 2014

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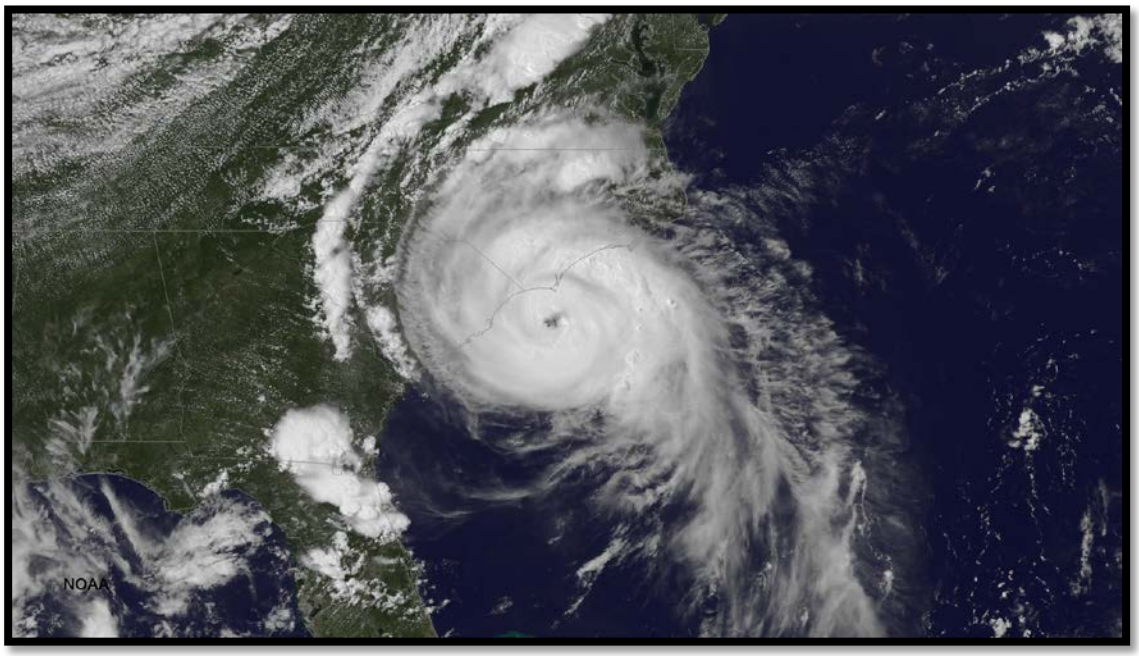

GOES-EAST VISIBLE SATELLITE IMAGE OF HURRICANE ARTHUR AT 1945 UTC 3 JULY 2014 BEFORE ITS LANDFALL ALONG THE NORTH CAROLINA COAST.

Having non-tropical origins, Arthur formed east of Florida and made landfall along the North Carolina coast as a category 2 hurricane (on the Saffir-Simpson Hurricane Wind Scale). After producing storm surge flooding and high winds on the Outer Banks, Arthur continued northeastward but stayed offshore of the Mid-Atlantic coast and New England, bringing minor impacts to southeastern Massachusetts. Arthur became an extratropical cyclone by the time it reached the Bay of Fundy just west of Nova Scotia and caused extensive tree damage and power outages across Atlantic Canada.

Hurricane Arthur

1 – 5 JULY 2014

SYNOPTIC HISTORY

On 25 June, showers and thunderstorms formed over the northwestern Gulf of Mexico in an area of upper-level diffluence ahead of a shortwave trough located over Texas. Weak low-level vorticity developed within the area of showers and thunderstorms during the day and moved northeastward across Louisiana, Mississippi, and Alabama through 26 June. The disturbance turned eastward later that day and moved across Georgia and South Carolina, where it became entangled with a weak frontal boundary. The front moved slowly southeastward, and low pressure developed just off the coast of South Carolina on 28 June. The low then moved generally southward during the next couple of days, becoming more organized over the warm waters of the Gulf Stream east of Florida. Deep convection became sufficiently well organized and persistent for the low to be designated as a tropical depression at 0000 UTC 1 July about 70 n mi north of Freeport in the Bahamas. The depression drifted westward and gradually strengthened, becoming a tropical storm by 1200 UTC about 60 n mi east of Ft. Pierce, Florida. The "best track" chart of Arthur's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1[1].

Arthur was located in a region of weak mid-level steering, and the cyclone meandered east of Florida until early on 2 July. Later that day, a mid-level anticyclone began building over the western Atlantic, causing Arthur to accelerate toward the north. Light upper-level winds and warm ocean temperatures near 28°C allowed Arthur to gradually strengthen while east of Florida, although mid-level dry air in the vicinity of the cyclone limited the rate of intensification. Arthur continued northward and became a hurricane at 0000 UTC 3 July while centered 125 n mi east-southeast of Savannah, Georgia.

On 3 July, Arthur turned north-northeastward and continued to accelerate while it moved between the ridge over the western Atlantic and an approaching mid- to upper-level trough over the eastern United States. The hurricane continued to strengthen, passed to the east of Cape Fear, and reached its peak intensity of 85 kt at 0000 UTC 4 July just off of the coast of North Carolina. Coastal radar data and aircraft reconnaissance data indicate that Arthur turned northeastward and made landfall on Shackleford Banks, just west of Cape Lookout, North Carolina, a few hours later at 0315 UTC. Over the next five hours or so, Arthur moved northeastward over Down East Carteret County and Pamlico Sound and crossed the Outer Banks just north of Oregon Inlet around 0800 UTC. Arthur is the earliest hurricane to make

[1] A digital record of the complete best track, including wind radii, can be found on line at ftp://ftp.nhc.noaa.gov/atcf. Data for the current year's storms are located in the *btk* directory, while previous years' data are located in the *archive* directory.

landfall in North Carolina since records began in 1851, surpassing the date when a hurricane made landfall between Kill Devil Hills and Kitty Hawk on 11 July 1901.

After crossing the Outer Banks, Arthur became increasingly embedded in the mid-latitude flow, and the hurricane accelerated northeastward over the western Atlantic late on 4 July and early on 5 July. At the same time, strong upper-level winds and much colder sea surface temperatures caused Arthur to lose some strength and begin extratropical transition, and the cyclone weakened to a tropical storm at 0600 UTC 5 July while located about 115 n mi east of Provincetown, Massachusetts (Cape Cod). Arthur became an extratropical cyclone 6 h later while over the Bay of Fundy just west of Nova Scotia.

The extratropical low continued generally northeastward toward the Gulf of St. Lawrence through 6 July, producing gale-force winds and heavy rain over portions of Nova Scotia, Prince Edward Island, and New Brunswick. The low then reached eastern Labrador (Newfoundland) late on 6 July and crossed into the far northwestern Atlantic over the Labrador Sea on 7 July. Over the next couple of days, the extratropical low's winds decreased below gale force, and the system dissipated off the eastern coast of Labrador by 0000 UTC 10 July.

METEOROLOGICAL STATISTICS

Observations in Arthur (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB). Data and imagery from NOAA polar-orbiting satellites including the Advanced Microwave Sounding Unit (AMSU), the NASA Tropical Rainfall Measuring Mission (TRMM), the European Space Agency's Advanced Scatterometer (ASCAT), and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track of Arthur.

Aircraft observations include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from ten flights of the 53rd Weather Reconnaissance Squadron of the U. S. Air Force Reserve Command and five flights of the NOAA Aircraft Operations Center (AOC) WP-3D aircraft. In addition, the NOAA AOC G-IV aircraft flew four synoptic surveillance flights around Arthur.

National Weather Service WSR-88D Doppler radar data from Melbourne, Florida; Jacksonville, Florida; Charleston, South Carolina; Wilmington, North Carolina; Morehead City, North Carolina; Wakefield, Virginia; Dover, Delaware; and Boston, Massachusetts, were used to make center fixes and obtain velocity data while Arthur was near the U. S. coast.

Ship reports of winds of tropical storm force associated with Arthur are given in Table 2, and selected surface observations from land stations and data buoys are given in Table 3.

Winds and Pressure

Although there were no aircraft missions during the morning hours of 1 July, a NOAA C-MAN site at Settlement Point on Grand Bahama Island measured a two-minute wind of 33 kt at 1220 UTC, supporting Arthur's upgrade to a 35-kt tropical storm at 1200 UTC.

Arthur is estimated to have become a hurricane around 0000 UTC 3 July. An Air Force reconnaissance mission measured a peak 850-mb flight-level wind of 75 kt at 2137 UTC 2 July, which is suggestive of peak surface winds around 60 kt. However, the SFMR also provided surface wind measurements between 65-70 kt on two separate missions during the day on 2 July. In addition, satellite intensity estimates from TAFB and SAB were T4.0 (65 kt) at 0000 UTC 3 July, and AMSU intensity estimates around that time ranged from 65 kt to 74 kt. A blend of these data supports the 65-kt estimate at 0000 UTC 3 July.

Arthur's estimated peak intensity of 85 kt beginning at 0000 UTC 4 July is based on a peak 700-mb flight-level wind of 94 kt at 0017 UTC 4 July, as well as SFMR measurements of 82 kt at 1837 UTC 3 July and 83 kt at 0313 UTC 4 July. Since Arthur made landfall along the North Carolina coast at 0315 UTC, these data also support the estimated 85-kt landfall intensity.

Arthur does not appear to have decreased in intensity while it was moving across Pamlico Sound and the Outer Banks. In fact, dropsonde data and surface observations suggest that the hurricane's minimum pressure occurred after it had made landfall and while the center was over Pamlico Sound. Data from a dropsonde released at 0008 UTC 4 July, a few hours before landfall, suggested that the minimum pressure was about 975 mb. Subsequently, a Weatherflow station located at Ft. Macon, North Carolina, just west of Arthur's landfall point, measured a minimum pressure of 974.1 mb at 0244 UTC. A couple of hours later, another Weatherflow station on Ocracoke Island measured a minimum pressure of 972.3 mb at 0505 UTC, while the center of Arthur was over southern Pamlico Sound. Therefore, Arthur's minimum pressure is estimated to be 972 mb around 0600 UTC. The central pressure began to gradually rise after that time, and a National Ocean Service (NOS) station and two Weatherflow stations near Oregon Inlet measured minimum pressures around 974 mb around the time of Arthur's second landfall in that area.

Sustained category 1 winds occurred across portions of extreme eastern North Carolina, especially the Outer Banks, while sustained category 2 winds were limited to marine areas of Pamlico Sound and offshore of the North Carolina coast. The highest sustained winds measured by surface stations were one-minute winds of 72 kt by a Weatherflow station in Salvo at 0753 UTC 4 July and 68 kt by a Weatherflow station in Pamlico Sound at 0554 UTC, and a two-minute wind of 67 kt by the C-MAN station at Cape Lookout at 0220 UTC. The highest measured wind gust was 88 kt at Cape Lookout, while the Weatherflow stations in Pamlico Sound and on Ocracoke Island each measured gusts to 86 kt. Figure 4 shows the maximum gusts that were observed across eastern North Carolina from Arthur.

Arthur steadily weakened after it moved away from North Carolina over the western Atlantic. Data from an Air Force mission during the morning of 4 July indicated that while there were still strong winds at flight level (95 kt measured at 1226 UTC), these winds were not effectively mixing down to the ocean surface. The highest surface winds measured by the SFMR on that mission were just under 70 kt. Still, the hurricane was large enough to produce

tropical-storm-force winds, especially in gusts, along the coasts of southeastern Virginia and the Delmarva Peninsula. Several stations in southeastern Virginia measured wind gusts around 50 kt.

Farther north, Arthur produced tropical-storm-force wind gusts along the coast of New England from Rhode Island to Maine from late on 4 July through 5 July. Sustained tropical-storm-force winds were confined to extreme southeastern Massachusetts and coastal Maine. In Massachusetts, Nantucket reported a two-minute wind of 43 kt with a gust to 55 kt, and Buzzards Bay reported a two-minute wind of 36 kt with a gust to 43 kt. In Maine, the C-MAN station at Matinicus Rock measured a two-minute wind of 39 kt with a gust to 47 kt, while a two-minute wind of 33 kt and a gust to 50 kt occurred at Eastport (both measurements occurred while Arthur was still a tropical cyclone).

Arthur produced strong winds across parts of Atlantic Canada during the last hours of its tropical phase and after it became extratropical; the strongest winds occurred east of Arthur's center over Nova Scotia on 5 July. On the coast, Brier Island measured a two-minute wind of 56 kt with a gust to 66 kt, while Yarmouth measured a gust to 61 kt. Farther inland, a wind gust to 75 kt was measured at Greenwood. Wind gusts to 50 kt were reported farther east in the Halifax area. On Prince Edward Island, the highest wind observation was a two-minute wind was 41 kt with a gust to 55 kt at Charlottetown. In New Brunswick, a two-minute wind of 37 kt with a gust to 57 kt was measured at Fredericton.

Storm Surge[2]

Arthur produced significant storm surge flooding along portions of the North Carolina coast, especially on the Outer Banks. The highest storm surge measured by an NOS tide gauge was 4.48 ft above normal tide levels at the Oregon Inlet Marina (sound-side). Storm surges between 2.0 and 2.6 ft were measured by the NOS gauges at Wrightsville Beach, Beaufort, Cape Hatteras (sound-side), and Duck (ocean-side).

Combined with the normal tide, Arthur's storm surge produced inundation of 3 to 5 ft above ground level on portions of the Outer Banks. The Oregon Inlet NOS tide gauge measured a storm tide of 3.47 ft above Mean Higher High Water (MHHW), suggestive of inundation levels between 3 and 4 ft above ground level in that area. A survey crew from the NWS office in Morehead City, NC, measured a high water mark of 5.2 ft above ground level farther south in Rodanthe. The crew also measured inundation levels of 3 ft in Salvo, 2.5 ft in Nags Head, and 2 ft in Buxton. Significant storm surge flooding also occurred on Roanoke Island at Manteo (5 ft above Mean Sea Level) and Down East Carteret County (up to 3 ft above

[2] Several terms are used to describe water levels due to a storm. **Storm surge** is defined as the abnormal rise of water generated by a storm, over and above the predicted astronomical tide, and is expressed in terms of height above normal tide levels. Because storm surge represents the deviation from normal water levels, it is not referenced to a vertical datum. **Storm tide** is defined as the water level due to the combination of storm surge and the astronomical tide, and is expressed in terms of height above a vertical datum, i.e. the North American Vertical Datum of 1988 (NAVD88) or Mean Lower Low Water (MLLW). **Inundation** is the total water level that occurs on normally dry ground as a result of the storm tide, and is expressed in terms of height above ground level. At the coast, normally dry land is roughly defined as areas higher than the normal high tide line, or Mean Higher High Water (MHHW).

Mean Sea Level). Figure 5 provides a map showing measured and estimated storm surge inundation heights along the coast of North Carolina from Arthur.

Arthur produced storm surges of 1 to 2 ft across extreme southeastern Massachusetts, but it did not result in any major flooding. The NOS tide gauge on Nantucket Island measured a storm surge of 2.02 ft, resulting in a storm tide of only 0.6 ft above MHHW.

Rainfall and Flooding

Arthur generally produced storm-total rainfall of 3-5 inches across portions of eastern North Carolina after it had become a tropical cyclone. The highest rainfall report was 4.53 inches near St. James in Brunswick County, along the coast south of Wilmington. Over 4 inches of rain was also reported farther inland at several locations in the Kinston area. The disturbance which became Arthur had originally moved across the Carolinas and produced heavy rainfall several days earlier. Over the entire period in which the incipient disturbance and Arthur affected the area, Myrtle Beach, Sound Carolina, reported a total of 8.73 inches of rain.

Heavy rainfall and minor flooding occurred across extreme southeastern Massachusetts and Down East Maine. Several locations in Massachusetts reported storm-total amounts of 6-8 inches, with a maximum of 8.00 inches being reported in New Bedford. Many locations in Down East Maine measured 4-6 inches of rain. The highest reported amount was 6.48 inches just west of Eastport near the town of Whiting.

While Nova Scotia experienced the strongest winds, the heaviest rain occurred on the back side of Arthur due to enhancement along a frontal boundary. Much like in Maine, many locations in New Brunswick measured 4-6 inches of rain. The highest rain amount reported by Environment Canada was 5.91 inches near Gagetown.

Tornadoes

Two tornadoes in North Carolina and two tornadoes in Virginia were reported in association with Arthur. An EF-1 (on the Enhanced Fujita Scale) tornado near Rose Hill in Duplin County, North Carolina, on 3 July damaged trees and two structures south of the town. A second EF-1 tornado occurred near Hamilton in Martin County, North Carolina, and snapped several large trees, blowing one down onto a house and causing an estimated $26,000 damage. Two EF-0 tornadoes were briefly on the ground in the cities of Virginia Beach and Norfolk, Virginia, each snapping and uprooting numerous trees.

CASUALTY AND DAMAGE STATISTICS

There were no reports of casualties associated with Arthur. Arthur is the strongest hurricane to make landfall in the mainland United States without being responsible for any direct deaths[3] since Hurricane Bret, which made landfall in a sparsely populated area of South Texas as a category 3 hurricane in 1999.

Arthur spared the United States significant damage, even though it made landfall as a category 2 hurricane. It should be noted, however, that the strongest sustained winds to affect land were of category 1 intensity, with sustained category 2 winds being limited to marine areas of Pamlico Sound and the western Atlantic Ocean. Property Claim Services (PCS) determined that Arthur did not meet their $25 million threshold in claims to be considered a "catastrophe" (Gregory 2014). Insurance broker BMS Group determined that Arthur is only the second category 2 hurricane to make landfall in the U.S. and not receive a PCS catastrophe designation (along with Hurricane Gerda, which made landfall in Down East Maine as a category 2 hurricane in 1969) (Siffert 2014).

Despite the relatively modest damage, one of the hardest hit areas was Dare County, North Carolina, which includes the Outer Banks. A report from the Dare County damage assessment officer indicated that most of the damage in the county was the result of sound-side storm surge flooding, but strong winds also downed trees and caused damage to shingles, siding, and roofs. Sixteen structures in the county had major damage, and 145 sustained minor damage. The worst damage occurred south of Oregon Inlet on Hatteras Island, especially in the Rodanthe, Salvo, and Waves areas, where wind and water damaged numerous residences, businesses, and campgrounds. More significant damage also occurred in Manteo, where sound-side flooding inundated businesses in the downtown area. Immediately after the storm, Dare County reported that total property damage in the county was just under $2 million (Dare County 2014). Duke Energy estimated that about 83,400 customers in North Carolina were without power at some point during the hurricane (Blythe 2014). Some parts of North Carolina Highway 12 were covered by sand due to storm surge, and the highway buckled near the Pea Island Bridge on Hatteras Island where the barrier island was breached during Hurricane Irene in 2011 (Dalesio 2014).

In New England, heavy rainfall caused flooding in parts of southeastern Massachusetts. Numerous roads were impassible and covered by up to a foot of water. A little more than 10,000 customers lost power, especially on Cape Cod. Fourth of July celebrations across the area were cancelled or rescheduled due to the inclement weather (Andersen and McNeill 2014). In Maine, strong winds and heavy rain helped to topple numerous large trees and power lines, causing extensive damage and knocking out power for about 20,000 customers (Gluckman 2014).

[3] Deaths occurring as a direct result of the forces of the tropical cyclone are referred to as "direct" deaths. These would include those persons who drowned in storm surge, rough seas, rip currents, and freshwater floods. Direct deaths also include casualties resulting from lightning and wind-related events (e.g., collapsing structures). Deaths occurring from such factors as heart attacks, house fires, electrocutions from downed power lines, vehicle accidents on wet roads, etc., are considered indirect" deaths.

Arthur knocked down numerous large trees and caused extensive power outages across Atlantic Canada due to strong winds during its post-tropical stage. About 290,000 homes and businesses lost power, including more than 140,000 NB Power customers in New Brunswick, 144,000 Nova Scotia Power customers, and 1,500 Marine Electric customers on Prince Edward Island (CBC News 2014a). Some customers in Nova Scotia and New Brunswick went without power for a week. Nova Scotia Power commented that the damage to the electrical grid caused by Arthur in some areas was as bad as that caused by category 2 Hurricane Juan in 2003 (CBC News 2014c). Heavy rain in New Brunswick resulted in localized flooding, with some streets being closed in the province's largest city of Saint John. Damage totals in New Brunswick alone were estimated to be C$12.6 million (Canadian Press 2014). The Gaspé region and Magdalen Islands of Quebec were also hit hard. Hydro Québec reported about 23,000 customers without power, and downed trees and power lines, as well as flooding, caused the closure of parts of Routes 123 and 198, major roads in the region (CBC News 2014b). Environment Canada reported that damage was particularly bad in the Carleton-sur-Mer area.

FORECAST AND WARNING CRITIQUE

The genesis of Arthur was well forecast, especially given its non-tropical origins. The possibility of genesis was first indicated in the Tropical Weather Outlook 5 days (120 h) before Arthur formed, when the incipient disturbance was located over the extreme northwestern Gulf of Mexico. The five-day chance of formation was raised to the "medium" category 3 days (72 h) before genesis and the "high" category just over 2 days (54 h) before genesis. Arthur was given a "low" chance of genesis in the 48-h Tropical Weather Outlook 78 h before it formed, which is considerably longer than the average lead time of 27 h for systems of non-tropical origin (Kimberlain 2014). The table below indicates how far in advance of genesis the NHC official genesis forecasts first reached the indicated likelihood categories:

	Hours Before Genesis	
	48-Hour Outlook	**120-Hour Outlook**
Low (<30%)	78	120
Medium (30%-50%)	60	72
High (>50%)	30	54

A verification of NHC official track forecasts for Arthur is given in Table 4a. Official forecast track errors were lower than the mean official errors for the previous 5-yr period for the 12- to 48-hr forecast times. The official track forecast errors were comparable to the previous 5-yr errors at 72 h and a little higher at 96 h. Figure 6(a) shows that the official forecasts had a slight eastward bias, initially keeping the center of Arthur farther offshore the coasts of North Carolina and Massachusetts. A homogeneous comparison of the official track errors with selected guidance models is given in Table 4b. Among the dynamical model guidance, the

National Weather Service's Global Forecast System (GFSI) and Hurricane Weather Research and Forecasting Model (HWFI), as well as Environment Canada's Global Environmental Multiscale Model (CMCI), performed well and had lower errors than the NHC official forecast at most forecast times. Figures 6(b) and 6(c) reveal that the GFS had a slight eastward bias in the forecast track of Arthur, especially off the coast of North Carolina, while the HWRF was highly consistent and displayed no apparent cross-track bias during Arthur's tropical phase. The Florida State Superensemble (FSSE) and the TCON fixed multi-model consensus also had lower errors than the official forecasts. The usually well-performing European Centre for Medium-range Weather Forecasting model (EMXI), on the other hand, had errors that were about two times larger than the official forecast errors, and Fig. 6(d) shows that the model had a significant eastward bias, keeping Arthur offshore of the coast of North Carolina and south of Nova Scotia. The official forecast track errors were consequently lower than the TVCA variable multi-model consensus, which includes EMXI as one of its member models, at all forecast times.

A verification of NHC official intensity forecasts for Arthur is given in Table 5a. Official forecast intensity errors were lower than the mean official errors for the previous 5-yr period for the 12-, 36-, 48-, and 96-h forecast periods. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 5b. In general, the official intensity forecasts had comparable or lower errors than the individual intensity models.

Watches and warnings associated with Arthur are given in Table 6. Coastal watches and warnings were not issued for North Carolina with the desired lead times, largely due to uncertainties of whether Arthur would move far enough west to produce strong winds along the coast. A hurricane watch was first issued from Bogue Inlet to Oregon Inlet, North Carolina, (including Pamlico Sound) at 0900 UTC 2 July. Tropical-storm-force winds first arrived on the coast of North Carolina by 2100 UTC 3 July, which means the hurricane watch only provided a lead time of about 36 h, instead of the normal 48 h. Likewise, a hurricane warning was issued from Surf City to Duck, North Carolina, (including Pamlico and eastern Albemarle Sounds) at 2100 UTC 2 July, which was only 24 h before the arrival of tropical-storm-force winds (instead of the typical 36 h). In New England, a tropical storm watch was not issued for extreme southeastern Massachusetts, but a tropical storm warning was eventually issued for Nantucket and from Chatham to Provincetown at 2100 UTC 3 July. The lead time for the warning was about 24 h, as sustained tropical-storm-force winds occurred at Buzzards Bay by 2300 UTC 4 July.

Hurricane Arthur provided the first opportunity for NHC to issue its experimental Potential Storm Surge Flooding Map to highlight areas near the coast that could experience inundation from storm surge. Figure 7 provides an example of the map that was available for Advisory 10 at 0900 UTC 3 July. In conjunction with the map, NHC first provided a storm surge forecast of 2 to 4 ft above ground level along the coast of North Carolina at 1500 UTC 2 July. The forecast was increased to 3 to 5 ft above ground level at 1500 UTC 3 July after there was more certainty that Arthur would not stay offshore of the coast of North Carolina. The earliest storm surge forecasts verified a little low (only by a foot or so), but the maximum inundation measurements of 5.2 ft at Rodanthe and 3.1 ft at Salvo on the Outer Banks verified well against the updated forecasts of 3 to 5 ft above ground level. Figure 8 compares measured inundation

heights along the coast of North Carolina against the experimental Potential Storm Surge Flooding Map at (a) 1500 UTC 2 July and (b) 0300 UTC 4 July.

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Table 1. Best track for Hurricane Arthur, 1-5 July 2014.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
28 / 1800	32.0	78.2	1017	20	low
29 / 0000	31.2	77.8	1017	20	"
29 / 0600	30.5	77.4	1017	20	"
29 / 1200	30.0	77.2	1016	20	"
29 / 1800	29.7	77.2	1015	25	"
30 / 0000	29.5	77.5	1014	25	"
30 / 0600	29.2	78.0	1013	25	"
30 / 1200	28.7	78.4	1011	25	"
30 / 1800	28.1	78.7	1010	30	"
01 / 0000	27.7	78.9	1008	30	tropical depression
01 / 0600	27.5	79.1	1007	30	"
01 / 1200	27.5	79.2	1005	35	tropical storm
01 / 1800	27.7	79.3	1003	40	"
02 / 0000	27.9	79.2	999	45	"
02 / 0600	28.2	79.1	995	50	"
02 / 1200	28.7	79.0	995	55	"
02 / 1800	29.4	79.1	994	60	"
03 / 0000	30.1	79.2	987	65	hurricane
03 / 0600	30.9	79.1	984	70	"
03 / 1200	31.8	78.8	981	80	"
03 / 1800	32.9	78.3	978	80	"
04 / 0000	34.0	77.3	975	85	"
04 / 0315	34.7	76.6	973	85	landfall on Shackleford Banks, NC
04 / 0600	35.3	76.0	972	85	"
04 / 0800	35.8	75.5	973	85	landfall just north of Oregon Inlet, NC
04 / 1200	36.8	74.4	976	80	"
04 / 1800	38.4	72.4	978	70	"
05 / 0000	40.2	69.7	976	65	"
05 / 0600	42.3	67.6	981	60	tropical storm

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
05 / 1200	44.1	66.5	982	60	extratropical
05 / 1800	45.9	65.3	980	55	"
06 / 0000	47.1	64.0	981	50	"
06 / 0600	47.6	62.4	982	45	"
06 / 1200	48.5	60.2	986	40	"
06 / 1800	50.3	58.1	989	35	"
07 / 0000	52.3	56.4	988	35	"
07 / 0600	54.2	55.4	985	35	"
07 / 1200	56.0	54.7	984	35	"
07 / 1800	57.3	54.2	985	40	"
08 / 0000	58.1	54.1	988	45	"
08 / 0600	58.9	54.7	991	40	"
08 / 1200	59.4	56.1	993	35	"
08 / 1800	60.0	57.0	995	30	"
09 / 0000	60.3	56.7	997	30	"
09 / 0600	60.1	56.2	1001	25	"
09 / 1200	59.8	55.7	1005	25	"
09 / 1800	59.5	55.0	1008	25	"
10 / 0000					dissipated
04 / 0600	35.3	76.0	972	85	minimum pressure and maximum winds
04 / 0315	34.7	76.6	973	85	landfall on Shackleford Banks, NC
04 / 0800	35.8	75.5	973	85	landfall just north of Oregon Inlet, NC

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Arthur, 1-5 July 2014.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
01 / 1500	C6SE3	26.7	79.1	210 / 36	1002.0
01 / 2100	C6SE3	28.1	78.2	130 / 44	1001.0
01 / 2300	C6SE3	28.6	77.8	120 / 35	1003.0
02 / 0300	C6PZ8	26.1	78.0	140 / 35	1014.0
02 / 0600	C6FM9	25.9	77.7	180 / 35	1006.0
03 / 1800	5BDK2	32.3	77.5	220 / 55	1004.0
04 / 0600	5BDK2	33.2	74.2	250 / 35	1017.0
04 / 1400	A8PQ5	38.6	74.9	350 / 40	1010.0
04 / 1500	KABP	38.5	74.5	010 / 42	1005.0
04 / 1600	KABP	38.3	74.5	340 / 55	1005.0
04 / 1700	KABP	38.1	74.6	340 / 50	1007.0
04 / 1800	3EUS	35.9	68.3	210 / 37	1017.2
04 / 1800	KABP	37.9	74.6	340 / 35	1009.0
04 / 1800	3EFD9	39.2	73.8	010 / 43	1005.8
04 / 2100	C6FT7	42.2	70.2	330 / 50	1006.0
05 / 1100	SHIP	44.6	63.5	120 / 35	998.9
05 / 1100	SHIP	45.1	66.1	050 / 35	987.0

Table 3. Selected surface observations for Hurricane Arthur, 1-5 July 2014.

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Bahamas									
Coastal-Marine Automated Network (C-MAN) Sites									
Settlement Point, Grand Bahama Island (26.70N 79.00W)	1/2200	1007.8	1/2230	41	53				
Florida									
C-MAN Sites									
St. Augustine (29.86N 81.26W)	2/2200	1012.2	2/1330	25	35				
National Ocean Service (NOS) Sites									
Virginia Key (25.73N 80.16)						0.94	0.76	0.6	
Lake Worth Pier (26.61N 80.03W)	1/2136	1009.4				1.28	1.44	0.9	
Trident Pier (28.41N 80.59W)	2/0906	1009.3				1.43	1.86	0.8	
I-295 Bridge, St. Johns River (30.19N 81.69W)	2/2148	1011.2				0.85	1.02	0.7	
Dames Point (30.38N 81.55W)						1.34	2.08	0.7	
Mayport (Bar Pilots Dock) (30.39N 81.43W)	3/0630	1012.6				1.57	2.81	0.9	
Fernandina Beach (30.67N 81.46W)	3/0654	1010.9				1.79	3.77	1.0	
South Carolina									
International Civil Aviation Organization (ICAO) Sites									
North Myrtle Beach (33.81N 78.72W)	3/2053	1004.1	3/1813	22	37				
NOS Sites									
Charleston (32.78N 79.92W)	3/1454	1009.2				1.45	3.65	1.0	
Oyster Landing (N Inlet Estuary) (33.35N 79.18W)						2.11	3.14	0.7	
Springmaid Pier (33.65N 78.91W)	3/1954	1004.3				2.38	3.19	0.7	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Citizen Weather Observer Program (CWOP) Sites									
Surfside Beach (33.62N 78.96W)			3/2103		37				
W2SWR-13 Little River (33.88N 78.62W)			3/1938		34				
Charleston (32.77N 79.93W)			3/1750		34				
North Carolina									
ICAO Sites									
Cedar Island (Piney Island) (35.02N 76.46W)	4/0356	979.7	4/0512	45	65				
Frisco (Mitchell) (35.22N 75.62W)	4/0651	990.5	4/0725	42	64				
Stumpy Point (Dare County Gunnery Range) (35.67N 75.90W)	4/0722	977.7	4/0611	44	63				
Cherry Point Marine Corps Air Station (34.89N 76.88W)	4/0330	993.6	4/0351	39	54				
Beaufort (34.72N 76.65W)	4/0258	980.7	4/0158	31	52				
Swansboro (Bogue Air Field) (34.69N 77.03W)	4/0257	992.2	4/0131	34	51				
Wilmington (34.27N 77.90W)	3/2353	999.6	3/2345	37	51				3.75
Elizabeth City (36.26N 76.17W)	4/0754	999.3	4/0954	31	45				
Kill Devil Hills (First Flight Airport) (36.01N 75.67W)	4/0815	983.1	4/0735	27	45				
Manteo (Dare County Airport) (35.91 75.70W)	4/0755	980.4	4/0635	30	45				
Southport (33.93N 78.08W)	3/2255	996.3	5/1855	29	41				
New River Marine Corps Air Station (34.70N 77.44W)	4/0156	999.7	4/0331	31	41				
New Bern (35.09N 77.05W)	4/0354	999.3	4/0454	23	40				
Currituck Airport (36.40N 76.02W)			4/0855	25	35				
Edenton (36.03N 76.57W)			4/0735	24	35				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
C-MAN Sites									
Cape Lookout (34.62N 76.53W)	4/0300	978.2	4/0220	67	88				
NOS Sites									
Wrightsville Beach (34.21N 77.78W)	3/2336	996.1	3/2230	40	54	2.60	2.41	0.7	
Wilmington (34.22N 77.95W)	3/2306	999.4				1.67		0.5	
Beaufort (34.72N 76.67W)	4/0318	979.0	4/0224	47	61	2.41		1.4	
USCG Station Hatteras (35.20N 75.70W)	4/0600	988.1	4/0548		79	2.51		1.8	
Oregon Inlet Marina (35.79N 75.54W)	4/0812	974.9	4/0924	47	60	4.48	3.95	3.5	
Duck (36.18N 75.74W)	4/0854	989.5	4/0912	47	56	2.12	2.25	0.8	
Remote Automated Weather Stations (RAWS)									
Cedar Island (34.95N 76.27W)			4/0325	37	63				
Croatan (34.76N 76.89W)			4/0405		48				
Back Island (34.53N 77.72W)			4/0318		39				
Dare Bomb Range (35.76N 75.87W)			4/0628	33	38				
Beaufort (35.52N 76.93W)			4/0718		38				
Fairfield (35.54N 76.22W)			4/0817		35				
Elizabeth City (36.34N 76.27W)			4/1013		40				
Hydrometeorological Automated Data System (HADS) Sites (NWS)									
NCCAT Campus at Ocracoke (35.11N 75.98W)			4/0445	46					
Cedar Island Ferry Terminal (35.01N 76.31W)			4/0330	41					
Columbia Town Hall (35.91N 76.25W)	4/0715	994.5	4/0900	39					
Oriental Town Pier (35.02N 76.69W)			4/0245	39					

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Weatherflow									
Pamlico Sound (35.42N 75.83W)	4/0159	975.7	4/0554	68	86				
Ocracoke (35.13N 76.00W)	4/0505	972.3	4/0455	63	86				
Salvo (Kitty Hawk Kites Resort) (35.58N 75.47W)	4/0803	980.6	4/0753	72	83				
Frisco Woods (35.24N 76.70W)	4/0648	984.7	4/0643	62	79				
Salvo (REAL Slick) (35.57N 75.49W)	4/0519	982.0	4/0519	63	76				
Fort Macon (34.70N 76.61W)	4/0244	974.1	4/0409	56	76				
Waves (35.57N 75.49W)	4/0804	980.6	4/0804	64	75				
Avon Ocean (35.35N 75.50W)	4/0730	990.0	4/0626	63	73				
Buxton (35.26N 75.59W)	4/0650	989.6	4/0545	55	72				
Oregon Inlet Coast Guard (35.80N 75.54W)	4/0832	974.4	4/0731	57	70				
Oregon Inlet (35.80N 75.54W)	4/0817	973.5	4/0517	54	70				
Whalebone (Jennettes Pier) (35.91N 75.59W)	4/0815	975.6	4/0725	55	69				
Avon Sound (35.34N 75.50W)	4/0710	987.7	4/0715	56	67				
Hatteras High (35.26N 75.55W)	4/0645	987.3	4/0625	38	64				
Jockeys Ridge (35.95N 75.63W)	4/0827	979.1	4/0937	38	52				
Alligator River Bridge (35.90N 76.01W)	4/0735	986.4	4/0730	50	60				
CWOP Sites									
Atlantic Beach (34.71N 76.74W)			4/0400	47	56				
Wilmington (34.28N 77.84W)			3/1600		56				
Southport (33.91N 78.01W)			3/1630	38	50				
New Topsail Beach (34.35N 77.64W)			4/0257	33	49				
Sneads Ferry (34.53N 77.37W)			4/0122		45				
Newport (34.71N 76.93W)			3/1944		44				
Arapahoe (35.02N 76.82W)			4/0226		43				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Oriental (35.02N 76.70W)			4/0446		42				
Bald Head Island (33.86N 78.00W)			3/2336	36	41				
Havelock (34.87N 76.90W)			4/0252		41				
Mt. Olive (35.14N 77.91W)			3/1633		40				
Shiloh (36.25N 76.09W)			4/1210	26	39				
Corolla (36.32N 75.80W)			4/1440		35				
NWS High Water Mark Survey									
North River (34.78N 76.61W)							2.96 (MSL)		
Marshallberg (34.71N 76.52W)							3.06 (MSL)		
Davis (34.79N 76.45W)							1.30 (MSL)		
Lola (34.95N 76.28W)							1.10 (MSL)		
Salter Path (34.69N 76.88W)							2.26 (MSL)		
Manteo (Pirate's Cove Marina) (35.89N 75.64W)							5.00 (MSL)		
Rodanthe (35.60N 75.46W)							7.21 (MSL)	5.2	
Salvo (35.53N 75.47W)							5.25 (MSL)	3.1	
Salvo (35.53N 75.47W)							4.88 (MSL)	3.1	
Avon (35.34N 75.51W)							4.69 (MSL)		
Buxton (35.27N 75.53W)							3.42 (MSL)	0.8	
Buxton (35.26N 75.59W)							3.78 (MSL)	2.1	
Nags Head (35.91N 75.60W)							2.90 (MSL)	2.6	
Manteo (35.90N 75.66W)							3.86 (MSL)	1.2	
Other									
0.5 N St. James (33.94N 78.10W)									4.53
0.7 W Oak Island (33.91N 78.17W)									4.37
7 SE Kinston (35.20N 77.50W)									4.20

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
5 ESE Kinston (35.24N 77.51W)									4.18
1.3 ENE Bayshore (34.29N 77.77W)									4.10
4.1 SE Wilmington (34.18N 77.89W)									3.94
1.9 W St. James (33.93N 78.14W)									3.92
4.1 SE Wilmington (34.18N 77.89W)									3.91
2.3 SE Wilmington (34.20N 77.92W)									3.88
Robersonville (35.82N 77.25W)									3.84
0.7 N Bath (35.48N 76.81W)									3.70
5.8 WNW Southport (33.95N 78.11W)									3.68
4.6 NNE Kinston (35.33N 77.56W)									3.57
5.9 W Southport (33.92N 78.12W)									3.55
1.0 NE Southport (33.93N 78.01W)									3.49
6.1 WSW Snow Hill (35.41N 77.77W)									3.48
2.5 NW Castle Hayne (34.38N 77.93W)									3.40
Virginia									
ICAO Sites									
Virginia Beach (Oceana Naval Air Station) (36.83N 76.03W)	4/0944	1003.0	4/1256	33	47				
Melfa (Accomack Airport) (37.65N 75.77W)			4/1415	25	40				
Wallops Island (37.97N 75.47W)	4/1254	1007.9	4/1325	22	39				
Norfolk (Norfolk Naval Air Station) (36.96N 76.29W)	4/0859	1006.0	4/1140	31	38				
Newport News (37.14N 76.50W)	4/0851	1007.6	4/0737	23	36				
Hampton (Langley AFB) (37.09N 76.35W)	4/0822	1006.0	4/1116	26	35				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
C-MAN Sites									
Chesapeake Light (36.91N 75.71W)	4/1000	1001.1	4/1340	45	52				
NOS Sites									
Money Point (36.77N 76.30W)	4/0854	1004.3	4/1436	20	32	2.38		0.6	
Chesapeake Bay Bridge Tunnel (36.96N 76.11W)	4/0854	1003.9	4/1148	40	53	2.12		0.9	
Sewells Point (36.94N 76.33W)	4/0830	1005.3				2.10	2.28	0.7	
Yorktown USCG Training Center (37.22N 76.47W)	4/0924	1007.4	4/1506	30	36	1.66		0.6	
Windmill Point (37.61N 76.29W)						1.36		1.1	
Lewisetta (37.99N 76.46W)	4/0848	1010.6	4/2124	21	30	1.08	1.64	1.0	
Kiptopeke (37.16N 75.98W)			4/1312	39	49	1.82	1.66	0.6	
Wachapreague (37.60N 75.68W)	4/1106	1006.8	4/1406		34	1.44		0.3	
Rappahannock Light (37.53N 76.01W)			4/1300	47	52				
York River East Rear Range Light (37.25N 76.34W)			4/1200	35	43				
Willoughby Degaussing Station (36.97N 76.31W)			4/1342	30	37				
Cape Henry (27.9 m) (36.92N 76.00W)			4/1324	45	52				
Dominion Terminal Associates (36.96N 76.42W)			4/1518	27	39				
Chesapeake Bay Interpretive Buoy System									
Stingray Point (3 m) (37.55N 76.25W)			4/0920	31	36				
First Landing (3 m) (36.97N 76.04W)			4/1330	34	47				
Norfolk (3 m) (36.84N 76.29W)			4/1120		35				
Virginia Department of Transportation									
Coleman (37.24N 76.50W)			4/1506	38	39				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
RAWS									
Back Bay (36.67N 75.91W)			4/1327		38				
Chincoteague (37.99N 75.28W)			4/1527		36				
CWOP Sites									
Hampton (37.07N 76.29W)			4/1507		41				
Suffolk (36.72N 76.58W)			4/1224		38				
Norfolk (36.92N 76.19W)			4/1230		38				
Virginia Beach (36.75N 76.06W)			4/1308		35				
Parksley (37.73N 75.61W)			4/1348		34				
Other									
Fox Hill (37.08N 76.29W)									2.16
2.6 NNW Mattaponi (37.56N 76.80W)									2.05
3.6 SE Williamsburg (37.23N 76.66W)									2.04
5.8 W Poquoson (37.13N 76.49W)									1.98
0.9 NW Williamsburg (37.27N 76.72W)									1.66
Maryland									
ICAO Sites									
Ocean City (38.31N 75.12W)	4/1253	1008.7	4/1353	23	36				
Salisbury (Wicomico Airport) (38.34N 75.50W)	4/1254	1010.6	4/1318	22	36				1.11
NOS Sites									
Bishops Head (38.22N 76.03W)	4/0854	1010.8	4/1630	25	34	0.93	1.56	0.8	
Ocean City Inlet (38.32N 75.09W)	4/1306	1008.1	4/1412	32	39	1.20	1.22	0.4	
RAWS									
Assateague Island (38.08N 75.20W)			4/1440		40				
CWOP Sites									
Deal Island (38.13N 75.95W)			4/1430	26	34				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Other									
1 NW Cambridge (38.57N 76.09W)									2.89
Delaware									
NOS Sites									
Lewes (38.78N 75.12W)			4/1318	35	46	1.42	2.34	0.3	
Other									
Laurel (38.55N 75.57W)									3.35
Lewes (38.78N 75.15W)									3.01
New Jersey									
NOS Sites									
Ship John Shoal (39.30N 75.37W)						1.14		0.6	
Cape May (38.96N 74.96W)						1.45	2.82	0.4	
Atlantic City (39.35N 74.41W)	4/1724	1009.6				1.05	2.19	0.2	
Sandy Hook (40.46N 74.00W)						0.96	2.60	0.2	
New York									
NOS Sites									
The Battery (40.70N 74.01W)						0.84	2.44	0.2	
Kings Point (40.81N 73.76W)						0.82		0.0	
Montauk (41.04N 71.96W)	4/2236	1007.7				0.84	1.17	0.2	
Connecticut									
NOS Sites									
Bridgeport (41.17N 73.18W)						0.68	3.49	0.0	
New Haven (41.28N 72.90W)	4/2154	1009.8				0.63		0.0	
New London (41.36N 72.08W)	4/2318	1007.5				0.58	1.27	0.1	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Rhode Island									
NOS Sites									
Quonset Point (41.58N 71.41W)	5/0048	1007.4	4/2236	28	34	0.56		0.0	
Providence (41.80N 71.40W)	5/0100	1007.5				0.80	2.26	0.0	
Conimicut Light (41.71N 71.34W)	5/0106	1007.4	4/2254	30	37	0.64		0.0	
Newport (41.50N 71.32W)	5/0054	1005.9				0.66	2.00	0.0	
Other									
Little Compton (41.50N 71.17W)									4.40
South Kingstown (41.43N 71.55W)									3.98
Massachusetts									
ICAO Sites									
Nantucket (41.25N 70.06W)	5/0053	998.8	5/0153	43	55				
Martha's Vineyard (41.39N 70.61W)	5/0153	1002.8	4/2353	27	44				
Hyannis (41.66N 70.28W)	5/0256	1002.8	5/0230	25	41				
Chatham (41.68N 69.99W)	5/0252	1002.3	5/0352	17	39				
Milton (42.21N 71.11W)	5/0454	1008.9	5/0954	18	36				
Plymouth (41.90N 70.73W)	5/0152	1007.0	5/0121	23	34				
C-MAN Sites									
Buzzards Bay (41.40N 71.03W)	5/0100	1005.0	4/2250	36	43				
NOS Sites									
Nantucket Island (41.28N 70.09W)	5/0106	999.9	5/0048	32	49	2.02		0.6	
Woods Hole (41.52N 70.67W)	5/0142	1003.5				0.78	0.96	0.1	
Chatham (41.68N 69.95W)						1.51	2.89	0.0	
Fall River (41.70N 71.16W)	5/0048	1007.0				0.78		0.0	
Boston (42.35N 71.05W)	5/0518	1006.7				0.97	4.77	0.0	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Other									
New Bedford (41.66N 70.94W)									8.00
South Plymouth (41.95N 70.68W)									7.20
Mattapoisett (41.66N 70.81W)									7.00
3 WNW Kingston (41.99N 70.71W)									6.51
3 NW New Bedford (41.69N 70.98W)									6.36
Fairhaven (41.65N 70.82W)									6.34
Acushnet (41.68N 70.91W)									6.14
New Hampshire									
C-MAN Sites									
Isle of Shoals (42.97N 70.62W)	5/0800	1005.6	5/1610	30	42				
NOS Sites									
Fort Point (43.07N 70.71W)						0.62	4.40	0.0	
Maine									
ICAO Sites									
Bar Harbor (44.45N 68.36W)			5/0855		34				
Bangor (44.80N 68.82W)			5/1011		36				
Greenville (45.46N 69.60W)			5/1256		36				
Millinocket (45.65N 68.69W)			5/1239		35				
Houlton (46.12N 67.79W)					41				
Caribou (46.87N 68.02W)			5/1822		45				
Frenchville (47.29N 68.31W)			5/1753		40				
Portland (43.64N 70.30W)			5/1837		37				
C-MAN Sites									
Matinicus Rock (43.78N 68.86W)	5/0800	999.5	5/0920	39	47				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
NOS Sites									
Wells (43.32N 70.56W)	5/0642	1005.3				0.65		0.0	
Portland (43.65N 70.24W)	5/0730	1005.1				0.54	4.65	0.0	
Cutler Farris Wharf (44.65N 67.21W)	5/1054	988.7	5/1230	26	41	1.02	7.08	0.1	
Eastport (44.90N 66.98W)	5/1100	987.3	5/0936	33	50	0.76	9.30	0.0	
Other									
3 NNE Whiting									6.48
Pembroke									6.15
Moosehorn NWR									6.02
Machias									5.64
Moosehorn NWR									5.49
3 NW Addison									4.74
Topsfield									4.63
3 ESE Mapleton									4.62
1 WSW Pembroke									4.56
4 E East Machias									4.50
Eastport									4.44
2 ESE Princeton									4.36
Princeton									4.21
1 WNW Eastport									4.06
New Brunswick									
Point Lepreau (45.07N 66.45W)	5/1300	985.7	5/1600		37				
St. Stephen (45.20N 67.25W)			5/1100		42				
Saint John (45.32N 65.88W)	5/1500	983.8	5/1800		42				
Oromocto (45.83N 66.43W)			5/1300		41				
Fredericton (45.87N 66.53W)			5/1200	37	57				
Moncton (46.12N 64.68W)	5/1853	980.6	5/2245		37				
Bathurst (47.62N 65.75W)			5/1946		35				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Charlo (47.97N 66.32W)			6/0200		38				
Gagetown									5.91
St. Stephen									5.63
Noonan									5.51
Millville									5.00
Miramichi									4.80
Nova Scotia									
Brier Island (44.28N 66.35W)	5/1100	984.8	5/1600	56	66				
Yarmouth (43.83N 66.08W)	5/1000	982.7	5/1428	40	61				2.05
Kejimkujik (44.43N 65.20W)			5/2000		42				
Western Head (43.98N 64.67W)			5/1100	38	48				
Lunenberg (44.37N 64.30W)			5/1000	38	55				
McNabs Island (44.60N 63.53W)			5/1700	39	51				
Halifax (44.88N 63.50W)			5/1437	35	51				
Greenwood (44.98N 64.92W)			5/2100	48	75				
Kentville (45.07N 64.48W)			5/2200		45				
Debert (45.42N 63.47W)			5/1400		46				
Amherst (45.77N 64.23W)	5/1700	983.5	5/2100		43				
Beaver Island (44.82N 62.33W)			5/1800	41	50				
Caribou Point (45.77N 62.68W)			5/1400	41	53				
Tracadie (45.62N 61.68W)			5/1500		47				
Port Hawkesbury (45.67N 61.37W)			5/1600		40				
Hart Island (45.35N 60.98W)			5/1700		41				
Grand Etang (46.55N 61.05W)			5/2040		53				
North Mountain (46.82N 60.67W)			5/2100		36				
Sydney (46.17N 60.05W)			5/2000		45				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
St. Paul Island (47.23N 60.14W)			6/1300	44	54				
Prince Edward Island									
North Point (47.06N 64.00W)	6/0000	981.8	6/0500	36	44				1.06
Summerside (46.44N 63.84W)	5/2200	983.1	5/1600		46				
Harrington (46.34N 63.17W)			5/1700	35	53				
Charlottetown (46.29N 63.13W)			5/1700	41	55				
Saint Peters (46.45N 62.58W)			5/1800		46				
East Point (46.46N 61.99W)			5/1800		42				
Quebec									
Gaspé									2.64
Cap-d'Espoir (48.42N 64.32W)			5/1700	36	50				
New Carlisle (48.01N 65.33W)			5/1755		35				
Cap-Madeleine (49.25N 65.32W)			5/2350		46				
Ile aux Perroquets (50.22N 64.21W)			6/0000	35	45				
Sept-Iles (50.22N 66.27W)			5/2200		34				
Iles-de-la-Madeleine (47.42N 61.80W)	6/0800	982.6	6/0000		39				
Buoys									
NOAA									
Canaveral East (28.90N 78.46W)	2/0750	1004.8	2/1050	41	54				
Edisto (32.50N 79.01W)	3/1450	996.6	3/1550	44	58				
Onslow Bay Outer (34.21N 76.95W)	4/0120	977.3	4/0030	58	76				
Diamond Shoals (35.00N 75.40W)	4/0550	996.7	4/0600	48	64				
Virginia Beach (36.61N 74.84W)	4/1050	980.4	4/1220	44	62				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft)[c]	Storm tide (ft)[d]	Estimated Inundation (ft)[e]	Total rain (in)
	Date/ time (UTC)	Press. (mb)	Date/ time (UTC)[a]	Sustained (kt)[b]	Gust (kt)				
Texas Tower #4 (39.58N 72.60W)	4/1950	1000.5	4/2020	41	50				
Nantucket Sound (41.44N 70.19W)	5/0250	1000.0	5/0210	39	50				
Gulf of Maine (43.20N 69.13W)	5/0750	999.2	5/0920	33	41				
Coastal Ocean Research and Monitoring Program (CORMP)									
27 Miles SE of Wrightsville Beach, NC (3 m) (33.98N 77.36W)			4/0200	47	56				
5 Miles SE of Wrightsville Beach, NC (3 m) (34.14N 77.72W)			4/0200	33	44				
Ocean Crest Pier, NC (12.2 m) (33.91N 78.14W)			3/2347	34	43				
Carolinas Coastal Ocean Observing and Prediction System (Caro-COOPS)									
Sunset Nearshore (3 m) (33.84N 78.48W)			3/1500	25	35				
Capers Nearshore (3 m) (32.80N 79.62W)			3/1800		35				
Northeastern Regional Association of Coastal Ocean Observing Systems									
Northeast Channel (4 m) (42.33N 65.90W)			5/0650	45	60				
Jordan Basin (4 m) (43.49N 67.88W)			5/0830	39	49				
Eastern Maine Shelf (4 m) (44.10N 68.10W)			5/1030	33	42				
Environment Canada									
La Have Bank (42.51N 64.02W)	5/1000	1000.9	5/1000	37	47				
Halifax Harbour (44.50N 63.40W)	5/1500	994.3	5/1200	35	45				

[a] Date/time is for sustained wind when both sustained and gust are listed.
[b] Except as noted, sustained wind averaging periods for C-MAN and land-based reports are 2 min; buoy averaging periods are 8 min.

[c] Storm surge is water height above normal astronomical tide level.
[d] For most locations, storm tide is water height above the North American Vertical Datum of 1988 (NAVD88).
[e] Estimated inundation is the maximum height of water above ground. For NOS tide gauges, the height of the water above Mean Higher High Water (MHHW) is used as a proxy for inundation.

Table 4a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Arthur, 1-5 July 2014. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	**13.7**	**27.0**	**41.2**	**55.9**	117.0	179.4	
OCD5	30.2	85.7	161.5	239.8	422.8	724.8	
Forecasts	16	14	12	10	6	2	
OFCL (2009-13)	28.8	45.5	61.2	77.8	114.5	158.4	
OCD5 (2009-13)	48.2	100.1	160.2	220.8	326.6	410.7	

Table 4b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Arthur, 1-5 July 2014. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 4a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	12.8	26.1	44.6	68.6	156.1		
OCD5	31.3	93.7	185.2	282.4	525.0		
GFSI	15.1	**21.7**	**38.4**	**55.4**	**117.5**		
EMXI	20.2	42.7	80.8	130.3	309.2		
EGRI	15.0	33.0	67.2	110.9	202.9		
CMCI	**11.5**	**21.0**	**34.8**	**62.4**	158.6		
GHMI	15.1	29.2	48.4	**58.4**	**57.5**		
HWFI	13.9	**25.0**	**33.0**	**41.6**	**117.7**		
NAMI	21.6	42.6	86.5	154.7	258.9		
AEMI	16.2	27.6	45.6	69.6	169.2		
FSSE	13.9	**22.9**	**40.6**	**58.6**	**115.9**		
TCON	**12.7**	**24.0**	**42.2**	**62.9**	**121.8**		
TVCA	13.7	28.4	49.5	75.2	160.1		
BAMS	36.1	77.2	114.7	162.7	351.2		
BAMM	30.5	59.4	94.4	140.4	314.4		
BAMD	27.7	47.7	70.1	104.1	226.7		
Forecasts	12	11	9	7	3		

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Arthur, 1-5 July 2014. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	**5.6**	11.4	**11.7**	**11.5**	15.8	**5.0**	
OCD5	9.3	15.6	20.8	25.7	26.7	27.5	
Forecasts	16	14	12	10	6	2	
OFCL (2009-13)	6.3	9.7	11.9	13.7	15.3	15.4	
OCD5 (2009-13)	7.4	11.1	13.8	15.7	18.3	18.2	

Table 5b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Arthur, 1-5 July 2014. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 5a due to the homogeneity requirement.

Model ID	Forecast Period (h)						
	12	24	36	48	72	96	120
OFCL	6.0	11.9	11.8	11.1	14.0	5.0	
OCD5	9.9	16.0	20.5	24.4	20.4	19.0	
HWFI	8.7	13.6	15.5	13.0	**13.8**	10.0	
GHMI	**5.9**	**9.2**	12.5	15.2	**11.0**	5.0	
GFSI	9.8	13.9	13.8	14.0	**12.4**	7.0	
EMXI	8.3	13.2	16.0	16.7	14.2	**0.0**	
DSHP	7.7	**11.5**	**11.3**	11.4	16.2	25.0	
LGEM	7.8	**11.5**	13.5	14.6	**13.8**	**2.0**	
ICON	7.2	**11.4**	12.7	13.2	14.0	8.0	
IVCN	7.2	**11.4**	12.7	13.2	14.0	8.0	
FSSE	6.9	12.5	14.5	14.4	**11.6**	**1.0**	
Forecasts	15	13	11	9	5	1	

Table 6. Watch and warning summary for Hurricane Arthur, 1-5 July 2014.

Date/Time (UTC)	Action	Location
1 / 0300	Tropical Storm Watch issued	Fort Pierce to Flagler Beach, FL
2 / 0900	Hurricane Watch issued	Bogue Inlet to Oregon Inlet, NC and Pamlico Sound
2 / 0900	Tropical Storm Watch issued	South Santee River, SC to Bogue Inlet, NC
2 / 0900	Tropical Storm Watch issued	Oregon Inlet, NC to NC/VA border and eastern Albemarle Sound
2 / 0900	Tropical Storm Watch modified to	Sebastian Inlet to Flagler Beach, FL
2 / 1500	Tropical Storm Warning issued	Little River Inlet, SC to NC/VA border and Pamlico and eastern Albemarle Sounds
2 / 1500	Tropical Storm Watch modified to	South Santee River to Little River Inlet, SC
2 / 1500	Tropical Storm Watch discontinued	Oregon Inlet, NC to NC/VA border and eastern Albemarle Sound
2 / 1500	Tropical Storm Watch discontinued	Sebastian Inlet to Flagler Beach, FL
2 / 2100	Hurricane Warning issued	Surf City to Duck, NC and Pamlico and eastern Albemarle Sounds
2 / 2100	Tropical Storm Warning issued	South Santee River to Little River Inlet, SC
2 / 2100	Tropical Storm Warning issued	Duck, NC to Cape Charles Light, VA
2 / 2100	Tropical Storm Warning issued	Western Albemarle Sound
2 / 2100	Hurricane Watch issued	Little River Inlet, SC to Surf City, NC
2 / 2100	Tropical Storm Watch discontinued	All
2 / 2100	Hurricane Watch discontinued	Bogue Inlet to Oregon Inlet, NC and Pamlico Sound
2 / 2100	Tropical Storm Warning discontinued	Surf City to Duck, NC
3 / 0900	Hurricane Warning modified to	Surf City, NC to NC/VA border
3 / 0900	Tropical Storm Warning modified to	NC/VA border to Cape Charles Light, VA
3 / 2100	Tropical Storm Warning issued	Chatham to Provincetown, MA
3 / 2100	Tropical Storm Warning issued	Nantucket, MA
3 / 2100	Tropical Storm Watch issued	Port Maitland to Point Aconi, Nova Scotia
4 / 0100	Hurricane Watch discontinued	Little River Inlet, SC to Surf City, NC
4 / 0100	Tropical Storm Warning discontinued	South Santee River to Little River Inlet, SC
4 / 0300	Tropical Storm Watch issued	US/Canada border to Grand-Anse, New Brunswick

Date/Time (UTC)	Action	Location
4 / 0300	Tropical Storm Watch issued	Prince Edward Island
4 / 0300	Tropical Storm Watch modified to	All of Nova Scotia
4 / 0300	Tropical Storm Warning modified to	Cape Fear to Surf City, NC
4 / 0500	Tropical Storm Warning discontinued	Cape Fear to Surf City, NC
4 / 0700	Hurricane Warning modified to	Bogue Inlet, NC to NC/VA border
4 / 0900	Tropical Storm Warning modified to	Woods Hole to Provincetown, MA
4 / 0900	Hurricane Warning modified to	Cape Lookout, NC to NC/VA border
4 / 1100	Hurricane Warning modified to	Ocracoke Inlet to NC/VA border
4 / 1100	Hurricane Warning discontinued	Pamlico Sound
4 / 1300	Tropical Storm Warning issued	Digby (southward) to Porters Lake, Nova Scotia
4 / 1300	Tropical Storm Watch modified to	Digby (northward) to Porters Lake, Nova Scotia
4 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	US/Canada border to Grand-Anse, New Brunswick
4 / 1500	Tropical Storm Watch changed to Tropical Storm Warning	Prince Edward Island
4 / 1500	Tropical Storm Warning modified to	All of Nova Scotia
4 / 1500	Hurricane Warning discontinued	All
4 / 1500	Tropical Storm Warning discontinued	Western Albemarle Sound
4 / 1800	Tropical Storm Warning discontinued	NC/VA border to Cape Charles Light, VA
5 / 0900	Tropical Storm Warning discontinued	Woods Hole to Provincetown, MA
5 / 0900	Tropical Storm Warning discontinued	Nantucket, MA
6 / 0550	Tropical Storm Warning discontinued	US/Canada border to Grand-Anse, New Brunswick
6 / 0550	Tropical Storm Warning discontinued	Western Nova Scotia
6 / 1200	Tropical Storm Warning discontinued	Eastern Nova Scotia
6 / 1200	Tropical Storm Warning discontinued	Prince Edward Island

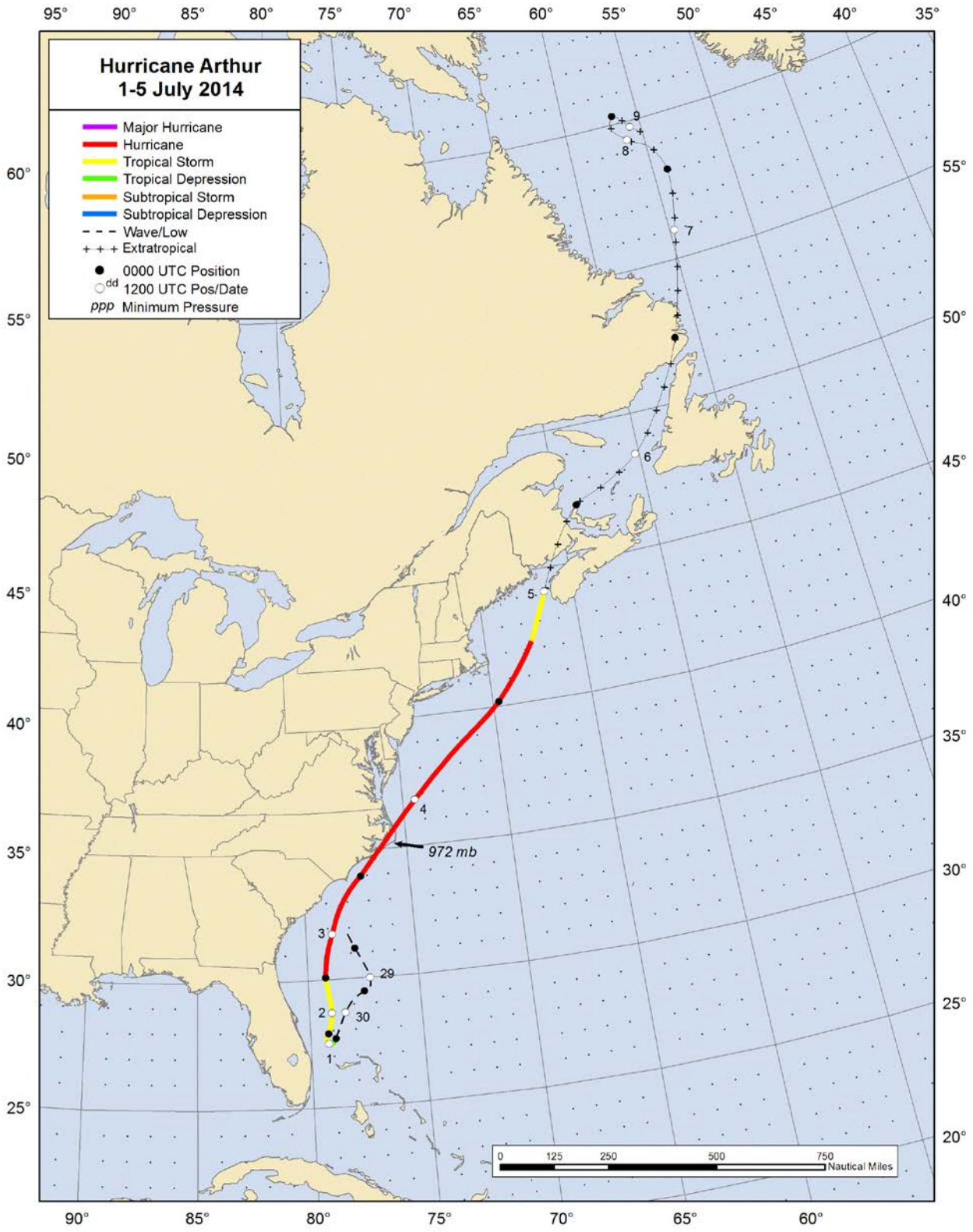

Figure 1. Best track positions for Hurricane Arthur, 1-5 July 2014. Track during the extratropical stage is partially based on analyses from the NOAA Ocean Prediction Center.

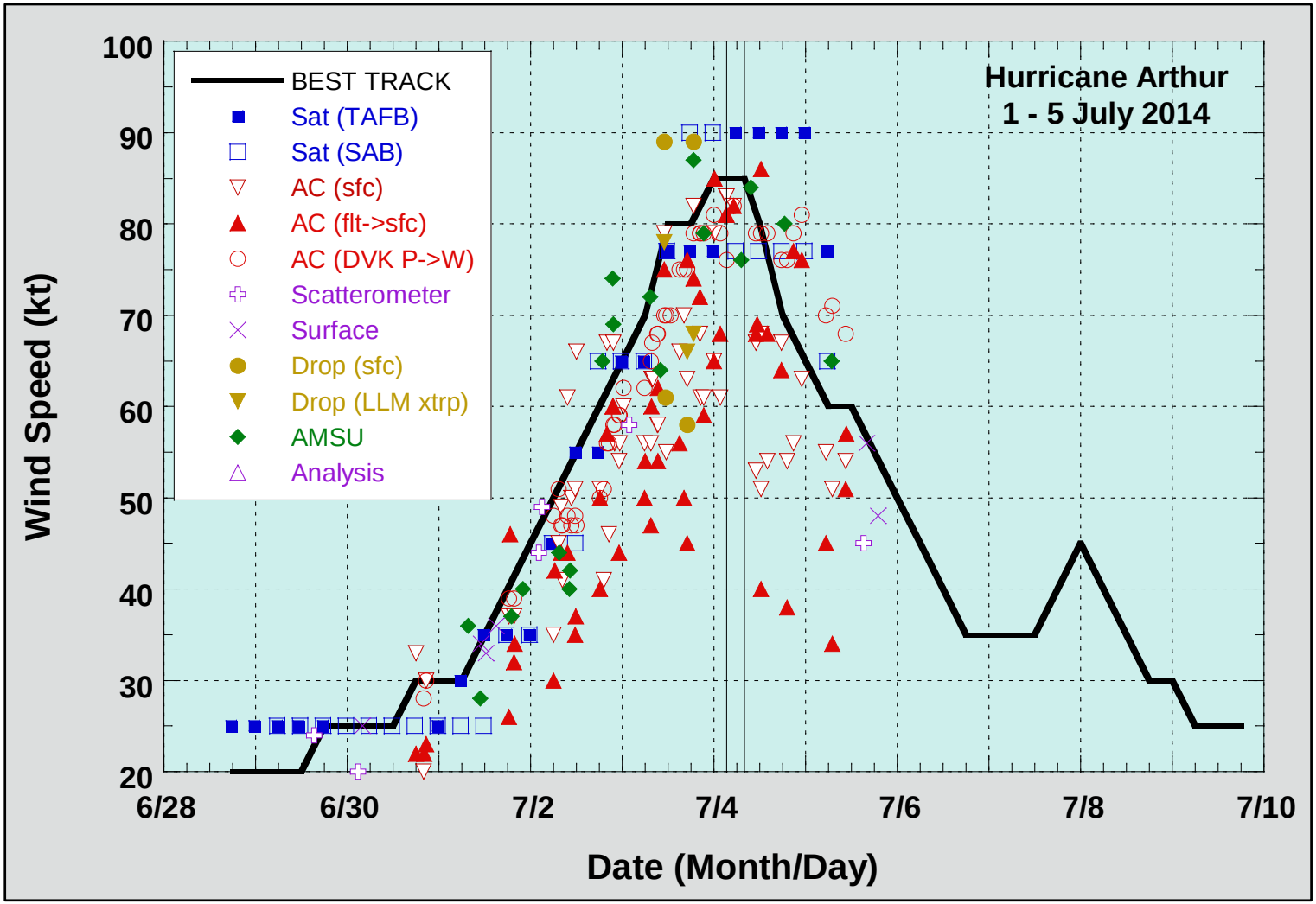

Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Arthur, 1-5 July 2014. Aircraft observations have been adjusted for elevation using 90%, 80%, 75%, and 80% adjustment factors for observations from 700 mb, 850 mb, 925 mb, and 1500 ft, respectively. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM). AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. Dashed vertical lines correspond to 0000 UTC, and solid vertical lines correspond to landfalls.

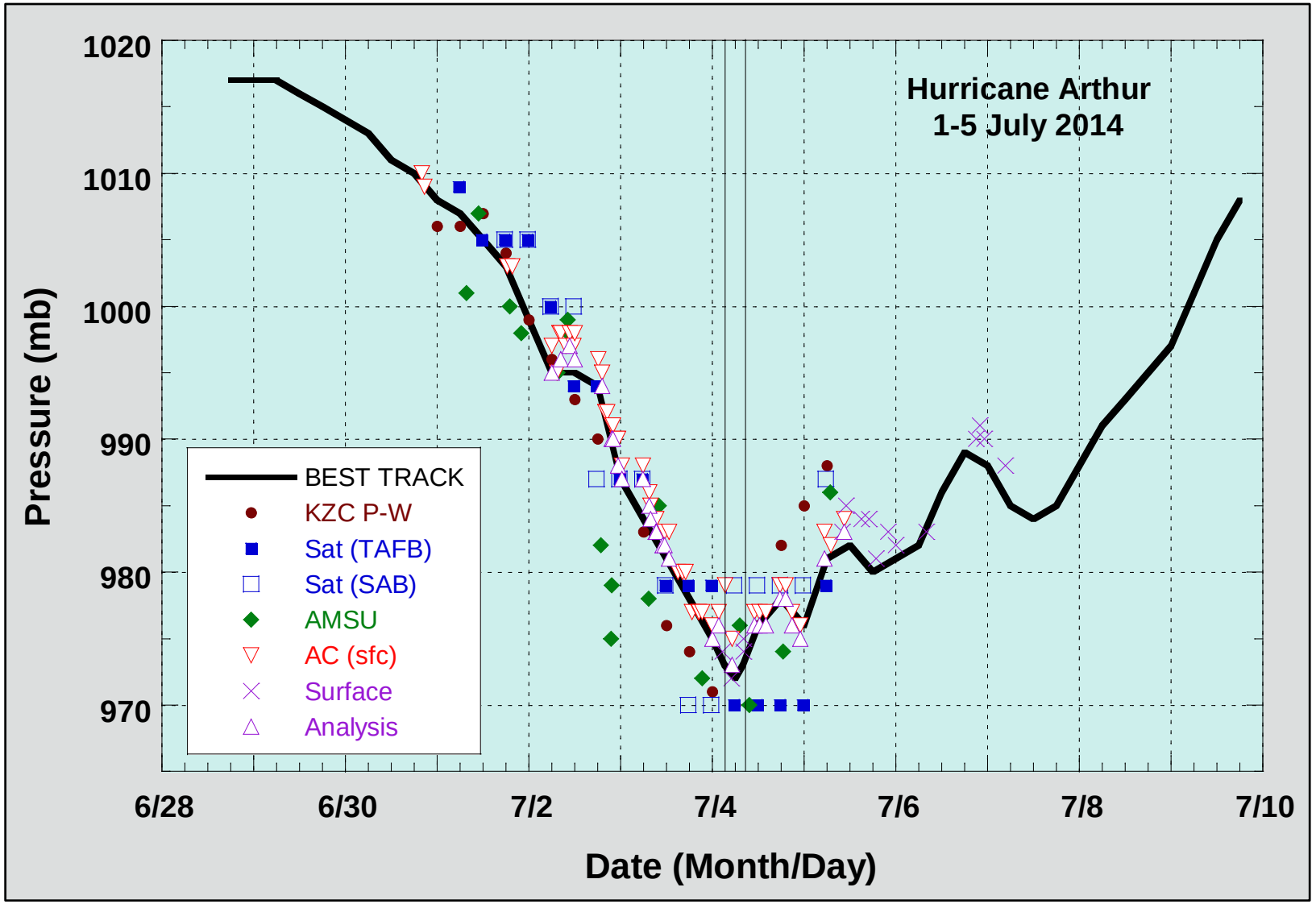

Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Arthur, 1-5 July 2014. AMSU intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies technique. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC, and solid vertical lines correspond to landfalls.

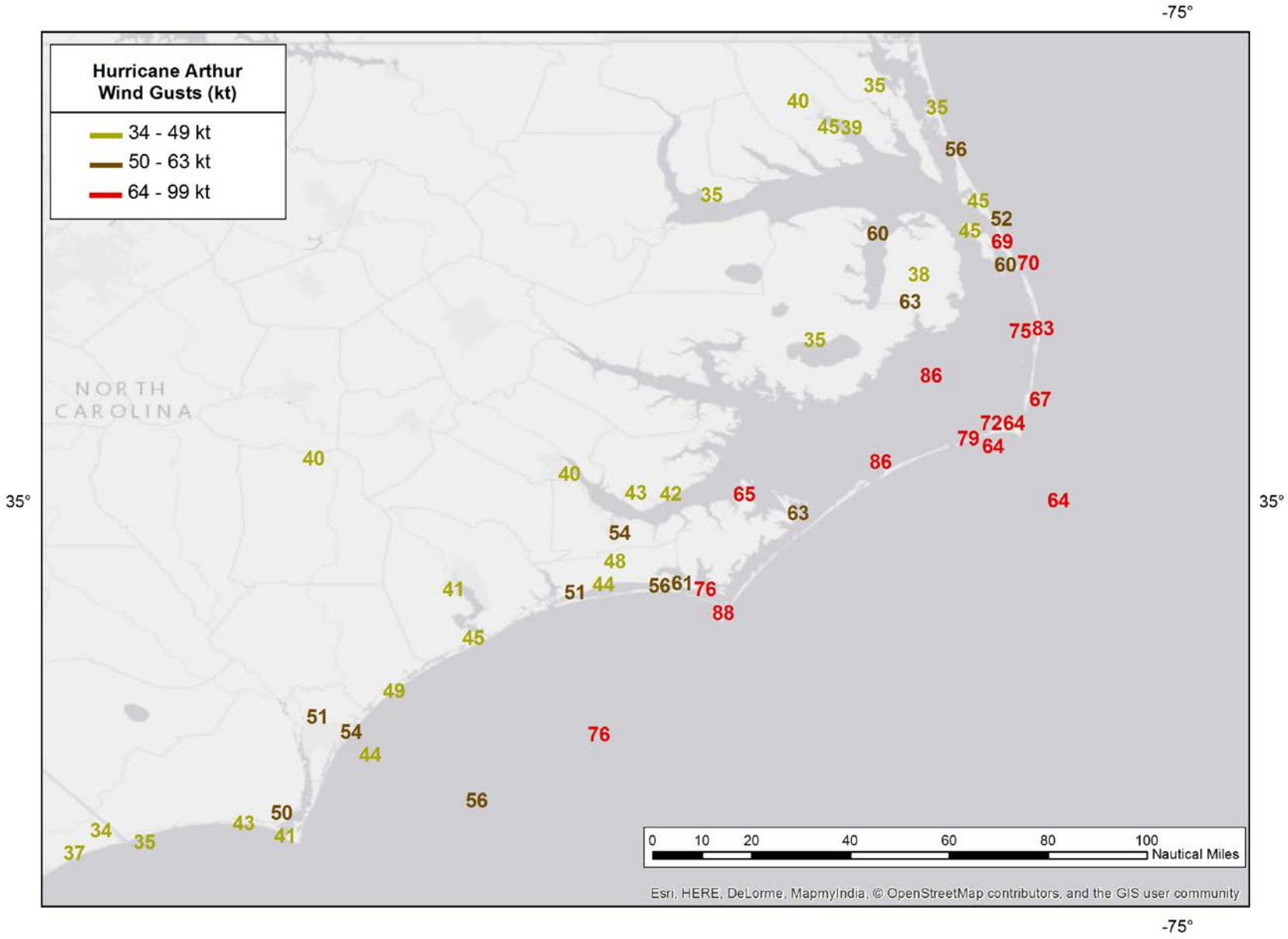

Figure 4. Map of select maximum wind gusts (kt) reported across coastal North Carolina from Hurricane Arthur.

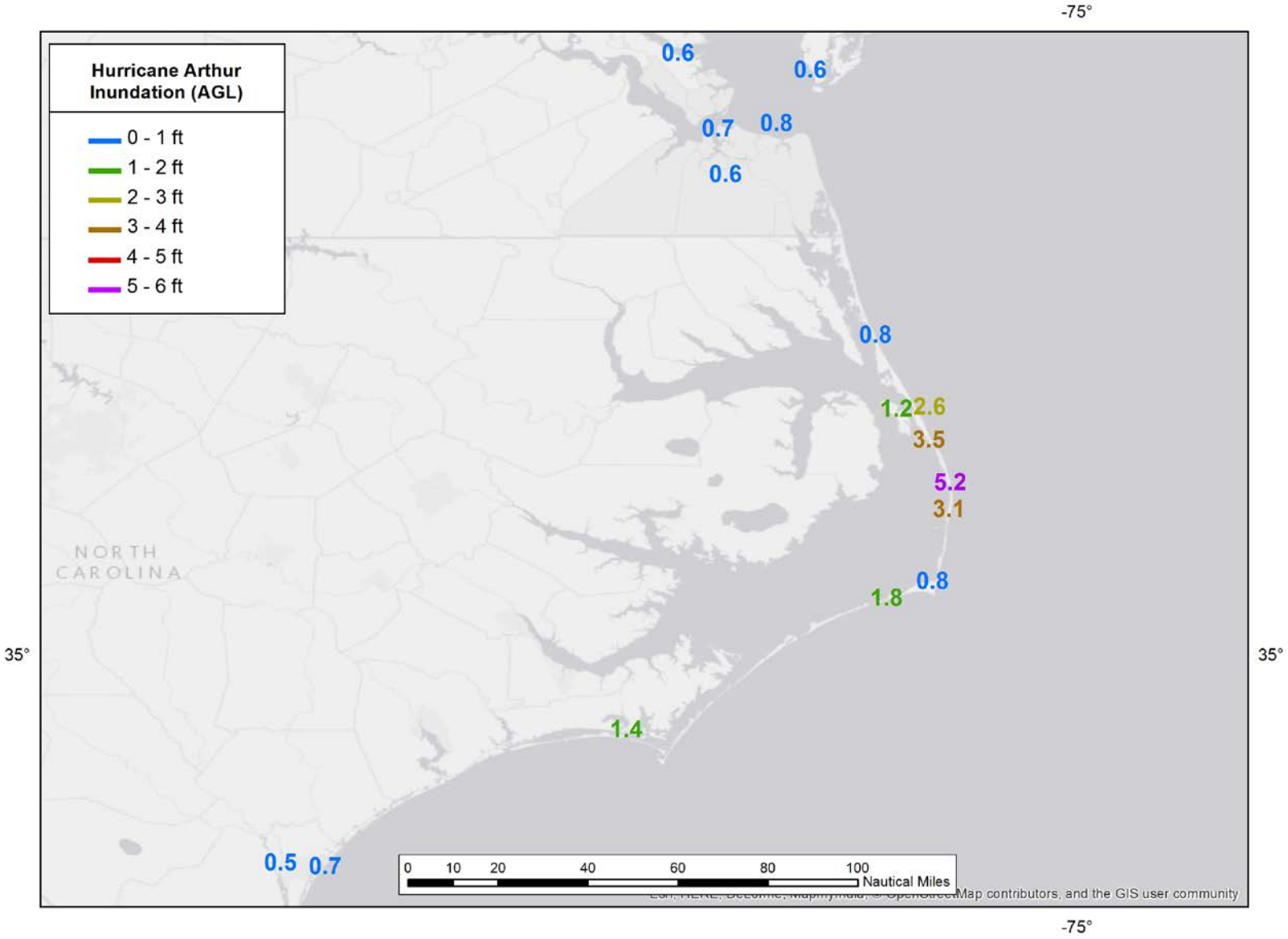

Figure 5. Map of measured and estimated storm surge inundation heights (ft above ground level) along the coast of North Carolina and southeastern Virginia from Hurricane Arthur.

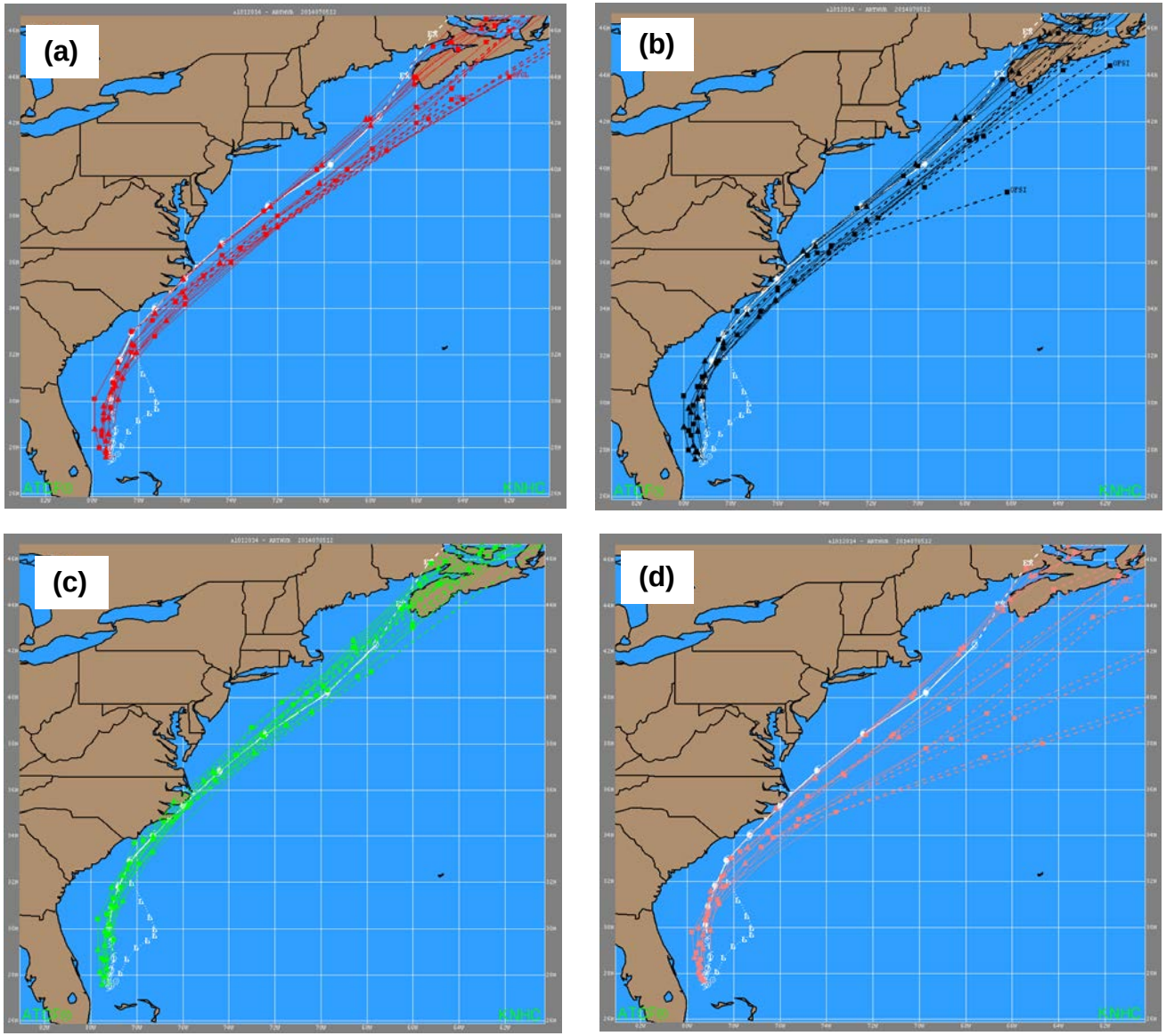

Figure 6. (a) Official track forecasts, (b) GFS forecasts, (c) HWRF forecasts, and (d) ECMWF forecasts for Hurricane Arthur, 1-5 July 2014 from 0000 UTC 1 July through 1200 UTC 5 July. The best track is given by the thick solid white line with positions given at 6-h intervals.

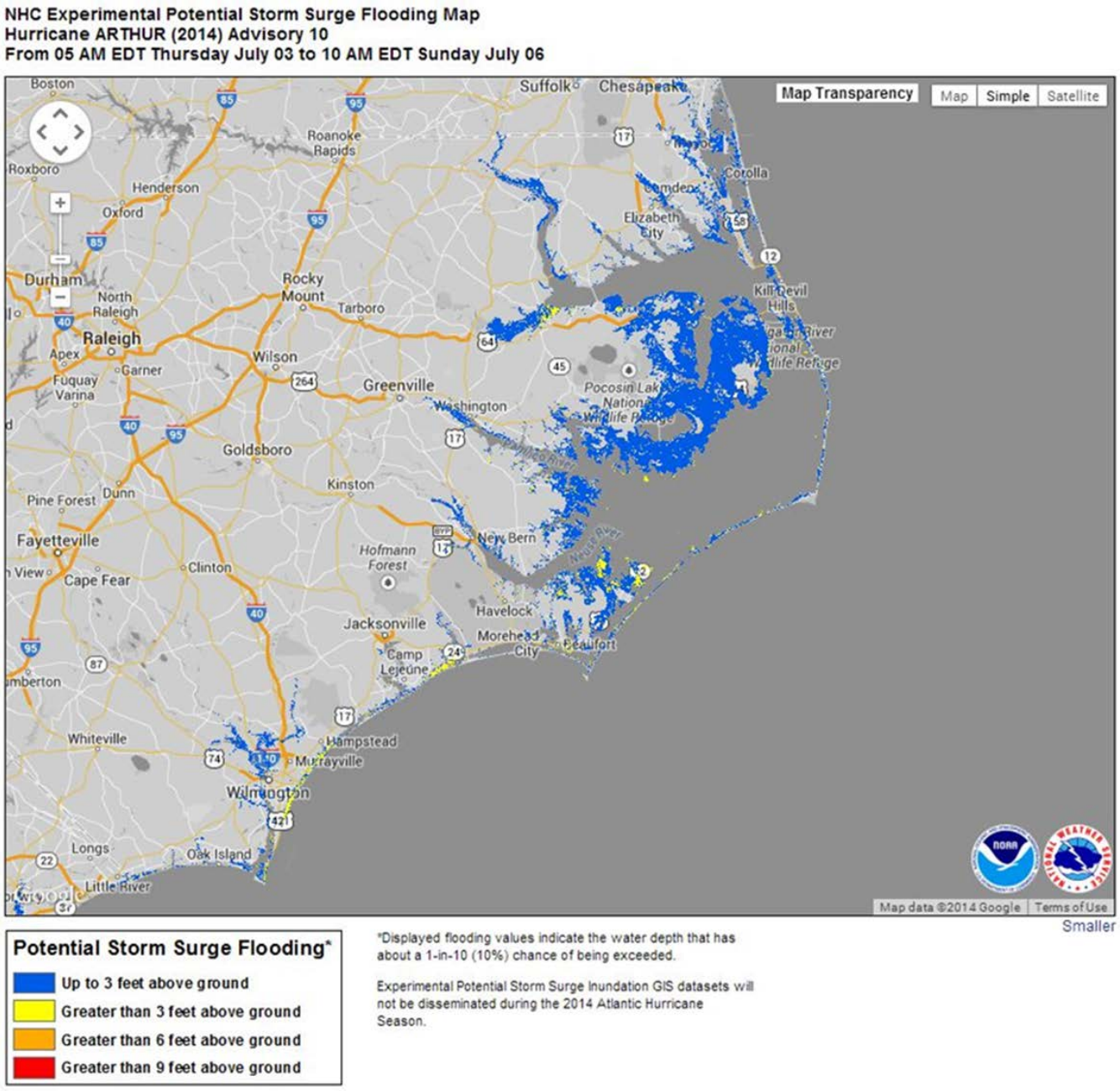

Figure 7. Example of the experimental NHC Potential Storm Surge Flooding Map, issued during Hurricane Arthur for the first time. This example was issued coincident with Advisory 10 for Hurricane Arthur around 0900 UTC 3 July 2014.

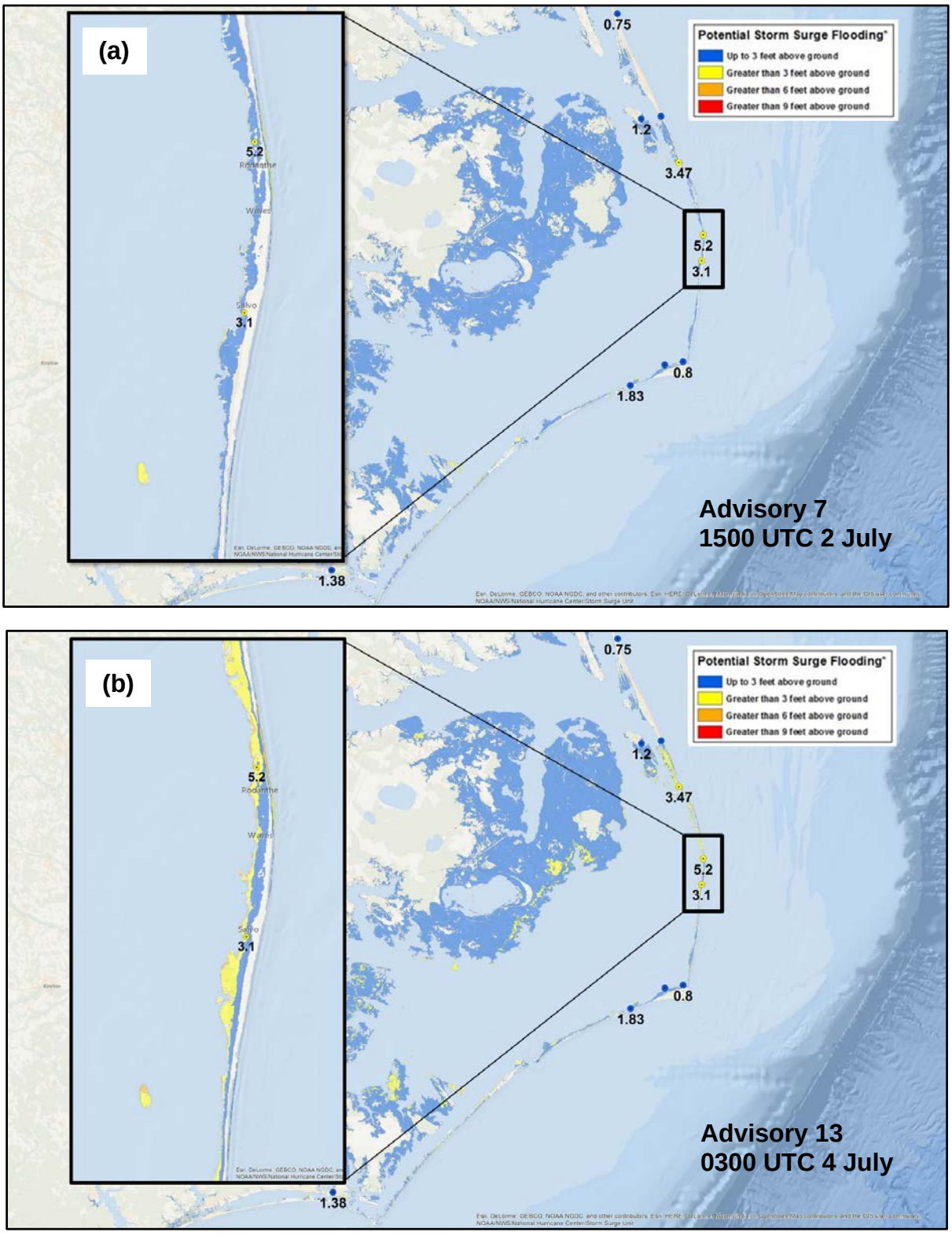

Figure 8. Measurements of storm surge inundation (in ft above ground level) verified against the experimental Potential Storm Surge Flooding Maps issued during Hurricane Arthur for (a) Advisory 7 (1500 UTC 2 July) and (b) Advisory 13 (0300 UTC 4 July). The inset on both figures provides a close-up view of the Rodanthe-Salvo area where the highest inundation occurred.